Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2019
August 4-9, 2019, New Orleans, LA, USA

The R83 Package: A new Type B(U) Fissile Package for Research Reactor Spent Fuels Transportation in the Netherlands

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ABSTRACT

Background
To cover the need of Nuclear Research and Consultancy Group (NRG) to transport used LEU fuel from the High Flux Reactor (HFR) in Petten and Hoger Onderwijs Reactor (HOR) in Delft to the inter-mediate storage facility HABOG at COVRA, Nieuwdorp, as well as waste from the Mo-99 production from its facilities in Petten, ROBATEL Industries has been selected to design, license and manufacture a new type B(U) fissile cask model, the R83.

ROBATEL Industries is a worldwide nuclear turnkey services provider, especially regarding bespoke radioactive material transportation casks. For decades it has designed numerous package models, type B ones especially which require regulators approvals. Based on such a broad experience, the company acquired a comprehensive knowledge of the technical issues related to safety and to inter-national regulations.

R83: a new versatile spent fuels type B cask
ROBATEL Industries delivered two R83 packages and their ancillary equipment early 2019. This package has been specifically thought from the beginning to complies with all the site constraints im-posed by the fact that the R83 replaces an old existing cask for which original interfaces had been designed for, and it allows an optimized shielding for current spent fuels to be transported and it was made future proof to be able to transport the future PALLAS reactor spent fuels.

Dedicated proprietary materials developed by ROBATEL Industries (phenolic foams FENOSOL™, and PNT7™) have been implemented, with an innovation in that the impact limiters have been filled with FENOSOL™ with two different foam densities per impact limiters to ensure high overall performance level, especially regarding suitable shock absorbing feature, efficient fire protection, while keeping the dimensions within limits.

The aim of this paper is to present this new R83 type B Fissile package design dedicated to the Research Reactor spent fuels transportation, describing the challenges and focusing on its specificities, mainly in terms of innovative implementation of materials and technical solutions.

INTRODUCTION

This paper aims to present one of the last type B(U) fissile package called "R83" designed by ROBATEL Industries. This model was designed for the Nuclear Research and Consultancy Group (NRG) to transport used LEU fuel from the High Flux Reactor (HFR) in Petten and Hoger Onderwijs Reactor (HOR) in Delft to the inter-mediate storage facility HABOG at COVRA, Nieuwdorp, as well as waste from the Mo-99 production from its facilities in Petten. The development of this cask from the early design to the safety authority approval and the manufacturing in less than 4 years only (2016-2019) was made possible thanks to the wide experience of ROBATEL Industries in the package transportation design and manufacturing. Indeed, from more than 60 years, ROBATEL Industries has managed the whole process of cask delivery: from the customer technical specification it designs the cask and the operating tools, builds the safety studies, obtains the approval certificate for type B packages, manufactures the casks and tools, performs the qualification tests …

The R83 designed has necessitate the full range of engineer skills encountered in the package transportation field : detailed safety shielding and criticality analysis using Monte-Carlos codes, crash simulations using explicit finite element codes, thermal calculation by finite element analysis taking into account specific materials like PNT7™ thermal shield and shock absorbing FENOSOL™ foam, drop tests on a specifically designed scale model, etc…

PRESENTATION OF THE R83 PACKAGE

R83 design overview

The R83 package is a type B(U) Fissile package of vertical cylindrical shape which weighs about 16.2 tons for overall dimensions of approximately 2.05 meters in diameter and 2.15 meters in height (including its impact limiters, see Figure 1).

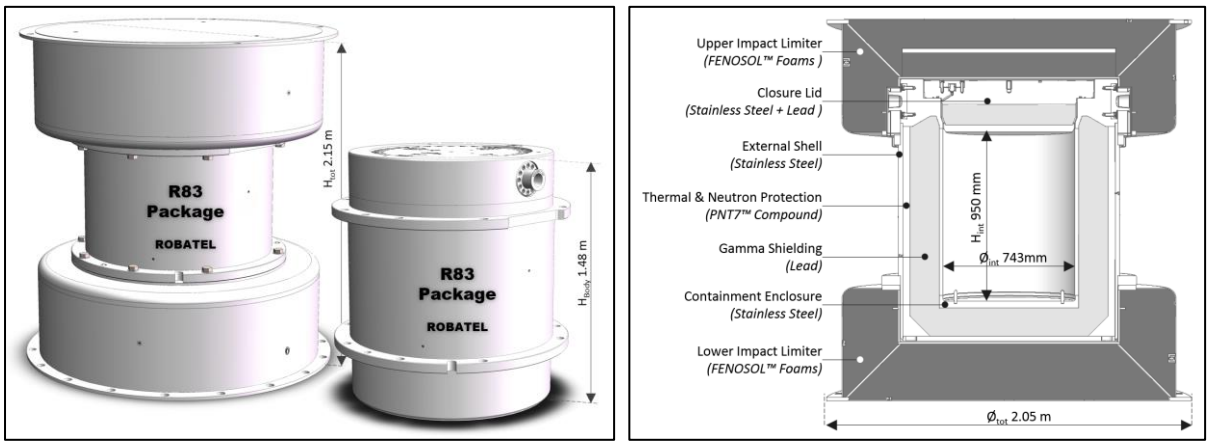


Figure 1: R83 package overviews

It has been designed to be transported vertically by road and is mainly composed of the following parts (see Figure 2):

- A cylindrical body constituted of inner and outer thick stainless steel enclosures (between 20 and 40 mm thick) between which are placed both a large gamma shielding

(about 165 mm layer of lead) and a neutron and thermal protection (around 40 mm layer made of compound ROBATEL PNT7™).

- A massive closure lid constituted of a robust stainless steel casing (up to 135 mm thick) which encapsulates a gamma shielding made of lead (115 mm thick). It is fixed on the body using 36 bolts and enables then, thanks to its O-rings it is equipped with, a high quality sealing of the package's containment enclosure.
- Two impact limiters which are stainless steel structures filled with the ROBATEL FENOSOL™ foams. They are fixed on the top and bottom of the body so as they provide both a mechanical protection and a thermal insulation in such a way the sensitive parts of the package (closure and sealing systems especially) are not damaged in case of hypothetical accident conditions (especially: 9.0 m drop tests, puncture test or fire test with respect to regulations).

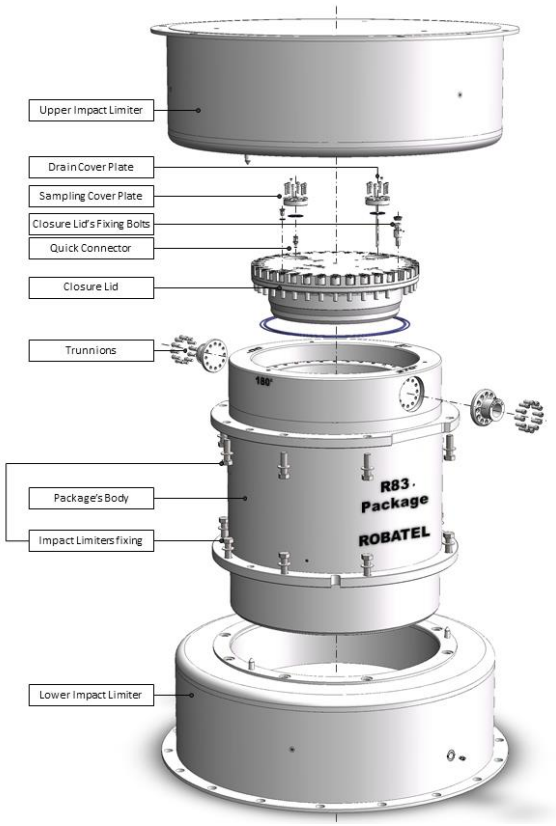


Figure 2: R83 package's components

The closure lid of the package is also equipped with suitable apertures which enable to access safely to the cask's cavity for operation needs (flooding, draining or drying in case of wet loading process for instance). These accesses are protected and sealed for transport purpose by 2 stainless steel cover plates. Besides, the cask's body is also equipped with 2 trunnions for on-site handling and lifting purposes.

R83 loading capabilities

The R83 package has been developed in order to transport Low Enriched Uranium (LEU with an initial ^{235}U enrichment $\leq$ 19.95%) spent fuels. They mainly consists in fuel and control assemblies or in Uranium Collecting Waste (UCW) filters wherein uranium residues has been collected.

For their loading into the cask's cavity (whose useful dimensions are Ø 743 mm x H 950 mm), suitable metallic baskets are used. Currently, 2 kinds of baskets have been developed to fit with the various transport needs (see Table 1), but other types of internals may also be developed to address any other specific issues.

From a general point of view, the overall loading capabilities of the R83 package are summarized hereafter by Table 2.

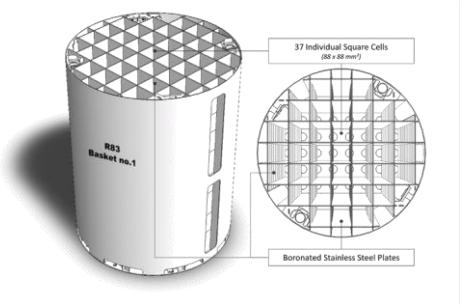
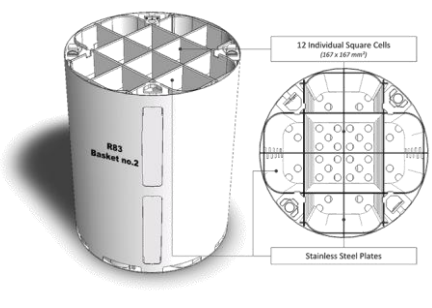
	Basket no.1	Basket no.2
Outer diameter	Ø 728 mm	Ø 728 mm
Cells number	37 cells	12 cells
Cells section	88 x 88 mm²	167 x 167 mm²
Cells height	910 mm	910 mm
Material	Boronated stainless steel	Stainless steel
Illustrations		

Table 1 : Overview of the R83 baskets

Total loaded mass *(basket & internal fittings weights included)*.....	≤ 1 000 kg
Total initial mass of fissile material *(^{235}U)*.....	≤ 20.75 kg
Total activity	≤ 10 PBq or 20 900 A2
Total residual heat.....	≤ 900 W

Table 2 : Overview of the R83 loading capabilities

R83 operation overview

The R83 package is dedicated to road transportation. Specific container including dedicated transport frame has been thereby designed to ensure safe use (see Figure 3).

The cask is operated vertically using its 2 trunnions (see Figure 3), either regarding its loading and unloading operation, but depending on facilities constraints, its design allows both wet loading (by immerging the cask's body in pond) and dry unloading (by interfacing the cask to hot cells for instance).

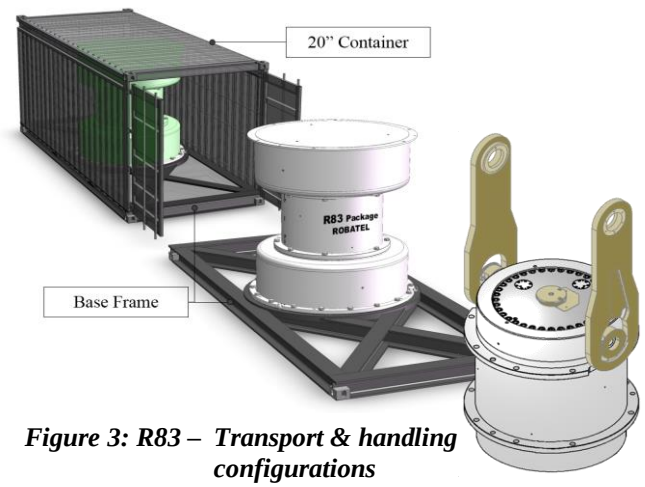


Figure 3: R83 – Transport & handling configurations

To this purpose, the package is equipped with dedicated interfaces and connections so as it enables to flood, drain and dry its cavity in safe and convenient way. Moreover, these devices and ports also make possible to fill the cask's cavity with an inert gas as needed (helium for instance for addressing heat dissipation or radiolysis issues if any).

CALCULATION, TESTS AND MANUFACTURE ASPECTS

Mechanical behavior during Accident Conditions of Transport

The resistance to accidental condition tests has been demonstrated by both calculations and tests (see Figure 4). The drops calculations were done using the LS-DYNA finite elements explicit code. Drop tests on the ROBATEL Industries facility have also been performed on a scale model specifically designed to be representative.

Both tests and simulations shown a good behavior of the shock absorbers and of the body. Specifically, no damage on the closure system was identified.

The shock absorber material is the ROBATEL Industries FENOSOL™ foam. This foam, jointly owned by ROBATEL Industries and by the CEA, is interesting in this application because of its shock absorbing capacity, its wide range of density allowing a fine tuning of its crush behavior and by the fact it doesn't propagate flames.

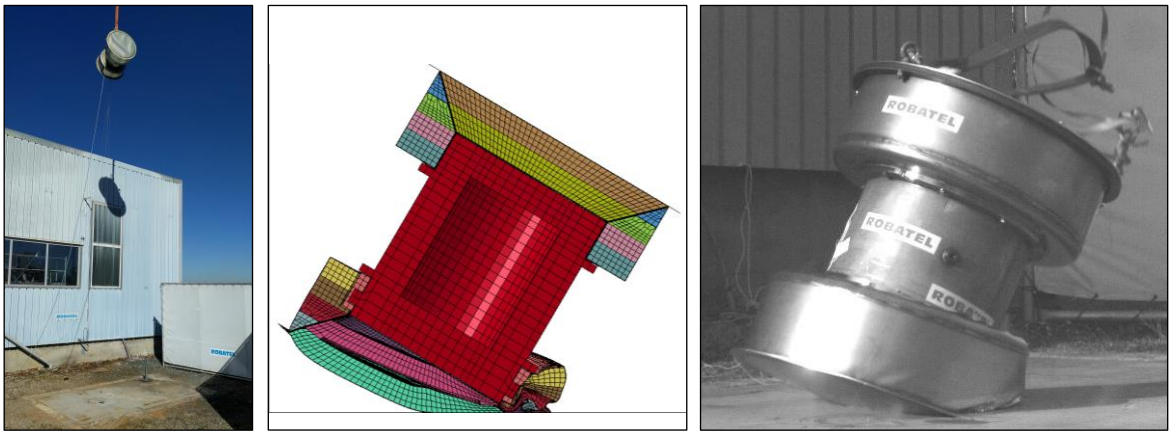


Figure 4: R83 – ACT Drop tests analyses

Thermal behavior assessments

A full thermal analysis has been done by finite elements calculation to verify the ability of the package to dissipate the content residual heat and its ability to resist to the regulatory fire test (see Figure 5).

The thermal protection against fire is addressed by both the FENOSOL™ foam and the PNT7™ concrete. The foam acts as a good thermal insulator whereas the PNT7™ compound has a more complex but very interesting behavior. It allows heat exchanges from the inner shell of the cask to its outer shell but, conversely, dissipates the heat coming from the fire test and so prevents the inner shell temperature to increase.

Besides, a thermal test has also been performed on the firsts R83 specimens manufactured to verify the efficiency of their internal heat dissipation capability (see Figure 5).

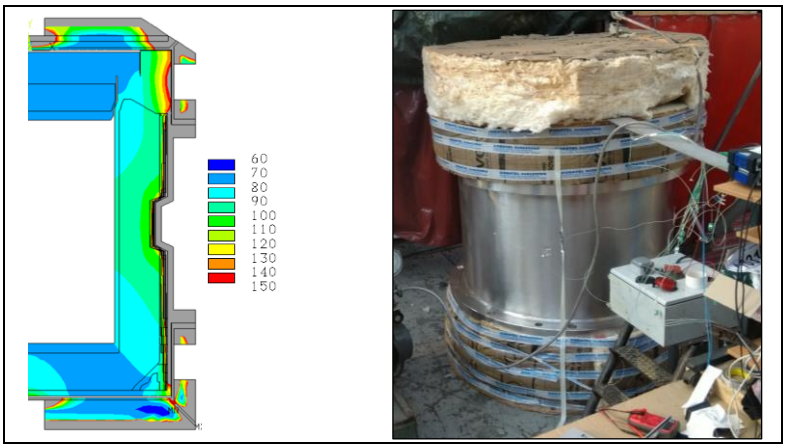


Figure 5: R83 – Thermal behavior assessments (left: ACT FEM calculations / right: NCT thermal tests)

Nuclear safety assessments: shielding & criticality calculations

Several dose rate evaluations and sub-criticality analyses were performed using the Monte-Carlo codes from the software package SCALE6 (from Oak Ridge National Laboratory). These calculations use detailed 3D models of the cask (see Figure 6).

The sub-criticality of the R83 package was assessed taking into account many parameters. One of the most influent is the assumption of water penetration inside the cask's cavity. Thousands of calculations were needed to verify the maintaining of sub-criticality whatever the conditions and configurations. In the worst case (related to the fuel assemblies), this has resulted in designing a basket made of boronated stainless steel.

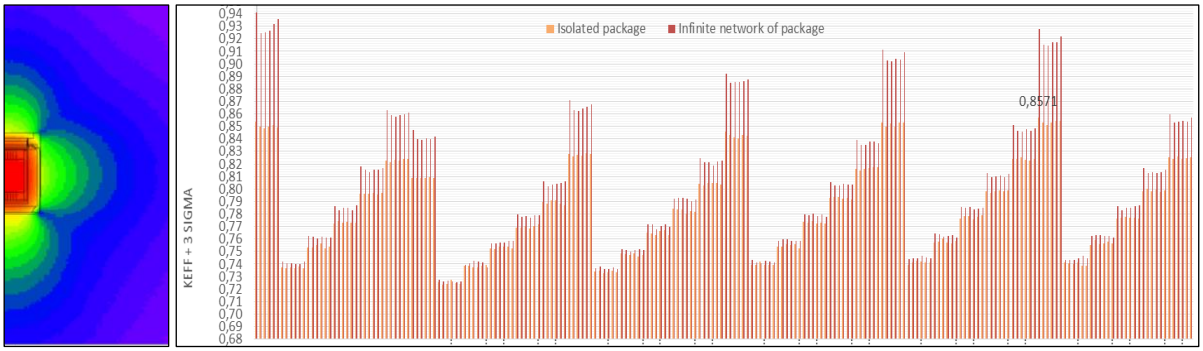


Figure 6: R83 – Left: Dose rates calculations / Right: Summary of the criticality analyses

CONCLUSION

The R83 package is a typical turnkeys' project were ROBATEL Industries excels. This project, which began by addressing the customer transportation issues regarding to the spent fuel and fissile waste to finally end with the design and delivery of a manufactured cask (see Figure 7) with its certificate of approval, was achieve in less than 4 years.

This cask, designed to transport fissile materials like spent fuels or fissile waste, has been fully optimized to the customer need: particularly, it may be loaded/unloaded under water or dry by docking it to a hot cell.

All the safety analysis and tests were carried out in house by the design engineers' team. The type B(U) certificate of approval was obtained in 3 years only from the contract signature. The R83 design takes indeed advantage of the materials commonly used by ROBATEL Industries (lead, PNT7™ concrete and FENOSOL™ foams especially: see Figure 8).

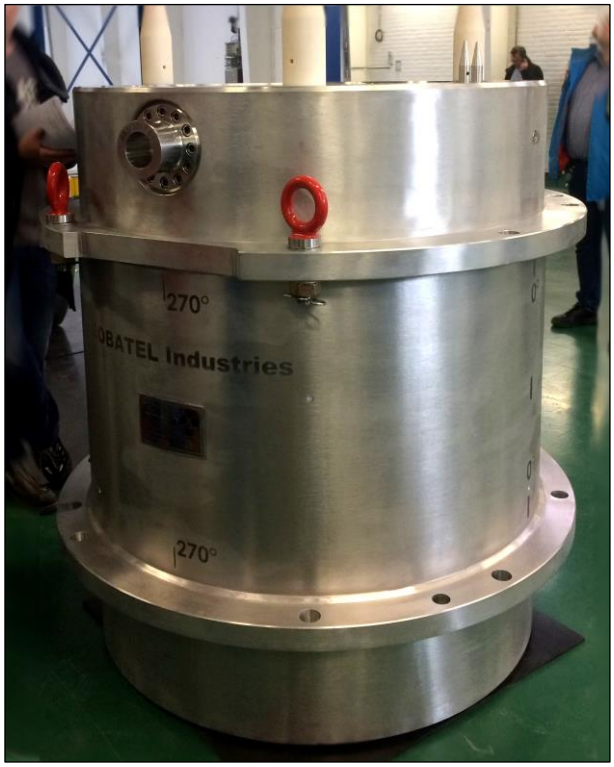


Figure 7: Picture of a R83's body

Figure 8: R83's impact limiter manufacturing (FENSOL™ foams)